Jun 27th, 4:05 PM - 4:25 PM

Session C3- A Broad level classification system for dam removals

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A Broad Level Classification System for Dam Removals

Presented By:

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A Broad Level Classification System for Dam Removals

Based on Experience with over 100 dam removals

(small dams, < 30 feet high, with a lot of eastern examples to date):

- Documented Dam Removals
- Historic Undocumented Dam Removals
- Dam Breaches/Failures
- Reservoir Drawdowns
- Post Glacial Lakes and Dams

Some obvious patterns and similarities in responses between specific "categories" of dam removals.

Uses & Needs:

- Conceptual Models – better predict outcomes/trends & project complexity (i.e define if a project maybe easy or difficult)
- Simple Economic Tool to Help Screen Potential Projects
- Identify Key Issues and guide management of impacts
- Compare similar sites (apples to apples)
- Understand Risks and Rewards at onset of project
- Frame regulatory questions/concerns
- Experience base such that research is more appropriately applied/extrapolated (avoid overgeneralizations)
- Focus monitoring efforts
- Help determine what (if any) numerical modeling maybe needed

How many “typical” dam removal categories exist?

Based on 2 Earlier Papers & Experience:

MacBroom, James, 2010. **"Evolution of Channels Upstream of Dam Removal Sites"**; ASCE Monograph on Sediment Dynamics Post Dam Removal.

Wildman, Laura, 2008. **"10 Dam Removals, 10 Years Later"**; 2008 Proceedings from the Association of Dam Safety Officials (ASDSO) National Conference.

Conceptual Model Framework

Defining Parameters

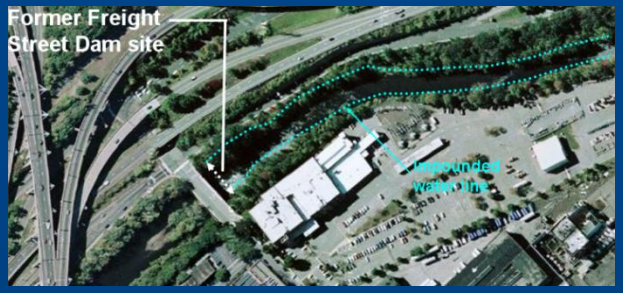
- **Quantity of Sediment** (no sediment, minimal sediment or significant sediment)
- **Limiting Factors** (quality of sediment, channel bed degradation, or dam sill left in place)
- **Narrow vs. Wide Impoundment**
- **Legacy Thalweg**
- **Type of Sediment**

Observed Response

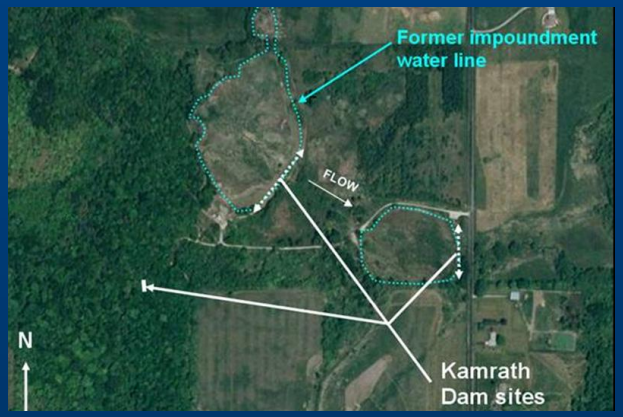
- **Channel Response**
- **Sediment Response**
- **System Response**

Examples

- **Similar Example Projects** (removals or breaches)



No sediment; narrow impoundment



No sediment; wide impoundment

Significant sediment; wide impoundment

Relative Recovery Rates (based on visual observation only at this time):

When is the removal of a dam a simple effort that could be completed quickly, at minimum cost, and with little to no potential for long term impact on the river system?

Which projects should include more detailed analysis and take more precautions before the dam is removed?

DAM REMOVAL CLASSIFICATION SYSTEM

START HERE

Little to No Sediment

SEDIMENT PRESENT?

YES

CONTAMINATED SEDIMENT FOUND IN IMPOUNDMENT, EXCEEDS BACKGROUD RIVERINE LEVELS

YES

Continue

RX (Contaminated Sediment)
Recovery Dependant on Sediment Management
(see contaminated sediment decision tree)

D/S CHANNEL DEGRADED or SOMETHING CAUSES CHANNEL TO INCISE BELOW THE ORIGINAL RIVERBED

YES

RL: Recovery Limited- Upstream channel headcuts below original riverbed.

DAM SILL LEFT IN PLACE, PARTIAL WIDTH REMOVAL OR NEW STRUCTURE ADDED

YES

RL: Recovery Limited- All or portion of U/S channel remains perched on Impounded sediments.

Uncontrolled headcut extends U/S of impoundment. Can lead to unraveling of U/S channel

Some possible impoundment-like characteristics remaining. System will down-cut when remained of sill/dam is eventually blown out or removed

Narrow (N) $W_{Imp} \approx W_{Ch}$

Wide (W) $W_{Imp} > 2W_{Ch}$

Narrow (N) $W_{Imp} \approx W_{Ch}$

NO

Highly Defined Legacy Channel? (L)

NO

Wide (W) $W_{Imp} > 2W_{Ch}$

NO

Significantly Wide (W+) W_{Imp} > Meander Belt W or $5W_{Ch}$

YES

YES

YES

YES

No Sediment (0)

Minimal Sediment (1)

Significant Sediment (2)

Significant Sediment (2)

Significant Sediment (2)

Significant Sediment (2)

Coarse Sediment (C)

Fine Sediment (F)

Coarse Sediment (C)

Fine Sediment (F)

Coarse Sediment (C)

Fine Cohesive (F_C)

Fine Non-Cohesive (F_{NC})

U/S Channel Response

Flow returns to pre-dam channel	Returns to pre-dam channel	Low sinuosity, Degrade to armor bed	Single stem; Degrade to regime slope	Returns to pre-dam channel & armor bed or pre-dam slope	Variable Sinuosity, May Degrade Or Bifurcate	Higher sinuosity Degrades to armor or equil. slope	Variable Sinuosity, May Degrade Or Bifurcate	Single stem, significant Degradation Or Bifurcation once channel widens	Higher sinuosity Degrades to armor or equil. slope

U/S Sediment Response

Exposed sediment will need time to revegetate	Stable little to no erosion	Gradual D / S transport both through headcut & surface erosion or diffusion	Headcuts, then widens; Accelerated D / S transport & suspension	Limited headcut if in-thalweg sediment remains. Overbank sediment remains	Headcut U/S then widening w/ some surface erosion & re-deposition. Overbank sediment remains	Incised channel, Lateral cuts, Floodplain formation	Headcut U/S then widening w/ some surface erosion & re-deposition. Overbank sediment remains	Incised channel, dramatic widening shifts	Incised channel, Lateral cuts, Floodplain formation

SEDIMENT MANAGEMENT OPTION IMPLEMENTED IF QUANTITY OF IMPOUNDED SEDIMENT EXCEEDS D/S CAPACITY

NO

System Response

Immediate 100% recovery	Full recovery within 1 growing season	Minor short term impact to no impact	Can cover D/S bed reaches for short period of time	Potential short term impacts due to turbidity	Recovery accelerated due to limited channel adjustment	Impact & timing dependant on quantity mobilized & D/S channel capacity	Potential short-term impacts due to turbidity, based on mobile quantity	potential to smother D/S reaches w/ extended recovery depending on carrying capacity	High sediment loads can greatly impact D/S system but much overbank sed. remains	High turbidity can greatly impact D/S system & remaining sediment consolidates

Classification & Example Sites

R0-N0	R1-W0	R2-N1	R3-N2C	R4-N2F	R5-W2L	R6-W2C	R7-W2F	R8-W+2C	R9-W+2F_c	R10-W+2F_{NC}	RL
Freight Street McGowan McPherrin Pizzini	Kamrath Dams Johnson State College Dam	Edwards Bushy Hill Chase Brass Seber	Union City Yoakum Brook West Heinkiker Gruendyke Pursel Mill	Castle Fin	Cuddebackville Raymond Brook	Anaconda Community Lake Bilington St. Merrimack Village	Saw Mill Scovill Reservoir Glacial Lake Hitchcock Red Cedar Lake	Bunnels Pond Jenkins	Norwalk Mill Pond Ward Paper Mill Mackenzie Lake Whitney Brewster Creek	Zemko Plimco Plainsboro-Canberry	Platts Mill Union City Millport Conservancy Lake Switzerland Mad River

Relative Recovery Rate

Simple Project. Quick 100% Recovery, No Remnant sediment

Small to moderate amount of sediment, most mobilizes within <5yrs

Complex Project
Slow Recovery
lg. amt. of sediment remains on overbank

Recovery Limited; May Never Fully Recover

DAM REMOVAL CLASSIFICATION SYSTEM

START HERE

SEDIMENT PRESENT?

Little to No Sediment

YES

CONTAMINATED SEDIMENT FOUND IN IMPOUNDMENT, EXCEEDS BACKGROUD RIVERINE LEVELS

YES

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Fine Sediment (F)

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Fine Cohesive (F_C)

Fine Non-Cohesive (F_{NC})

U/S Channel Response

Flow returns to pre-dam channel

armor bed

pre-dam slope

slope

once channel widens

slope

U/S alignment & bed limits on erosion

U/S Sediment Response

Exposed sediment will need time to revegetate

diffusion

transport & suspension

sediment remains

formation

Overbank sediment remains

shifts

formation

Type of transport process & revegetation; quantity of remaining sediment

SEDIMENT MANAGEMENT OPTION IMPLEMENTED IF QUANTITY OF IMPOUNDED SEDIMENT EXCEEDS D/S CAPACITY

NO

System Response

Immediate 100% recovery

Full recovery within 1 growing season

of time

channel capacity

carrying capacity

remains

consolidates

Recovery timing & potential impact

Classification & Example Sites

R0-N0
Freight Street
McGowan
McPherrin
Pizzini

R1-W0
Kamrath Dams
Johnson State College Dam

R2-N1
Edwards
Bushy Hill
Chase Brass
Seber

R3-N2C
Union City
Yoakum Brook
West Heinkiker
Gruendyke
Pursel Mill

R4-N2F
Castle Fin

R5-W2L
Cuddebackville
Raymond Brook

R6-W2C
Anaconda
Community Lake
Bilington St.
Merrimack Village

R7-W2F
Saw Mill
Scovill Reservoir
Glacial Lake Hitchcock
Red Cedar Lake

R8-W+2C
Bunnels Pond
Jenkins

R9-W+2F_c
Norwalk Mill Pond
Ward Paper Mill
Mackenzie
Lake Whitney
Brewster Creek

R10-W+2F_{NC}
Zemko
Plimco
Plainsboro-Canberry

RL
Platts Mill
Union City
Millport Conservancy
Lake Switzerland
Mad River

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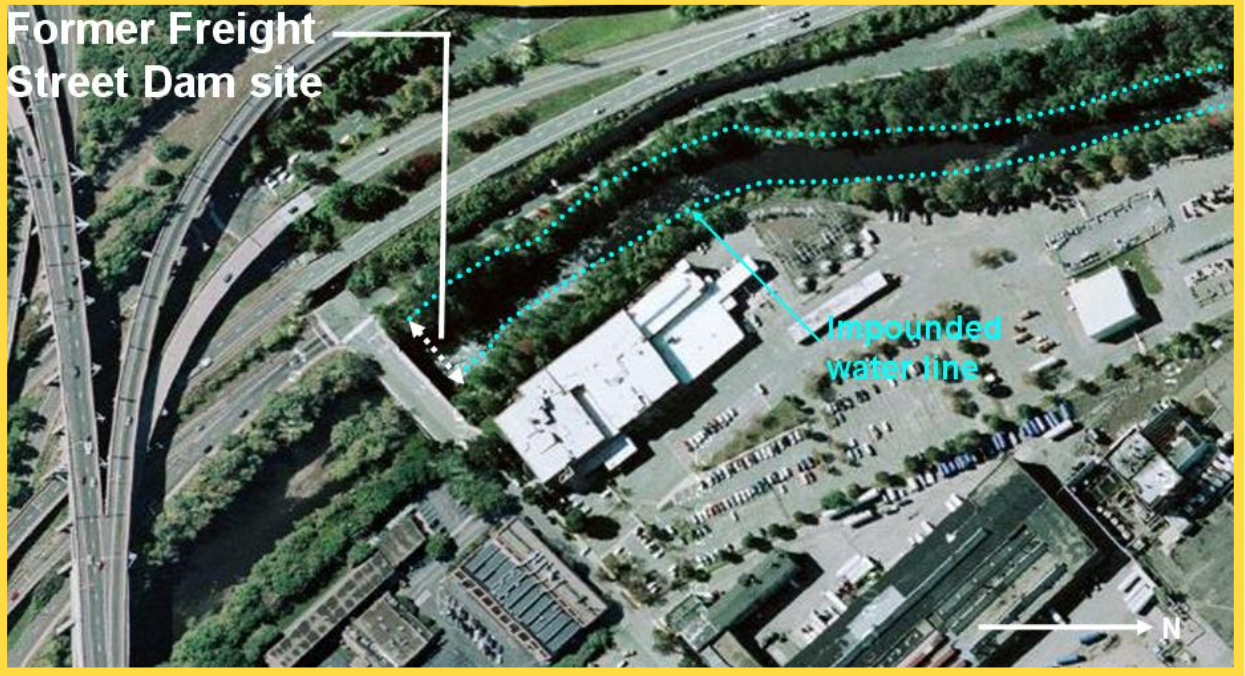

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U/S Sediment Response

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System Response

Immediate 100% recovery

Full recovery within 1 growing season

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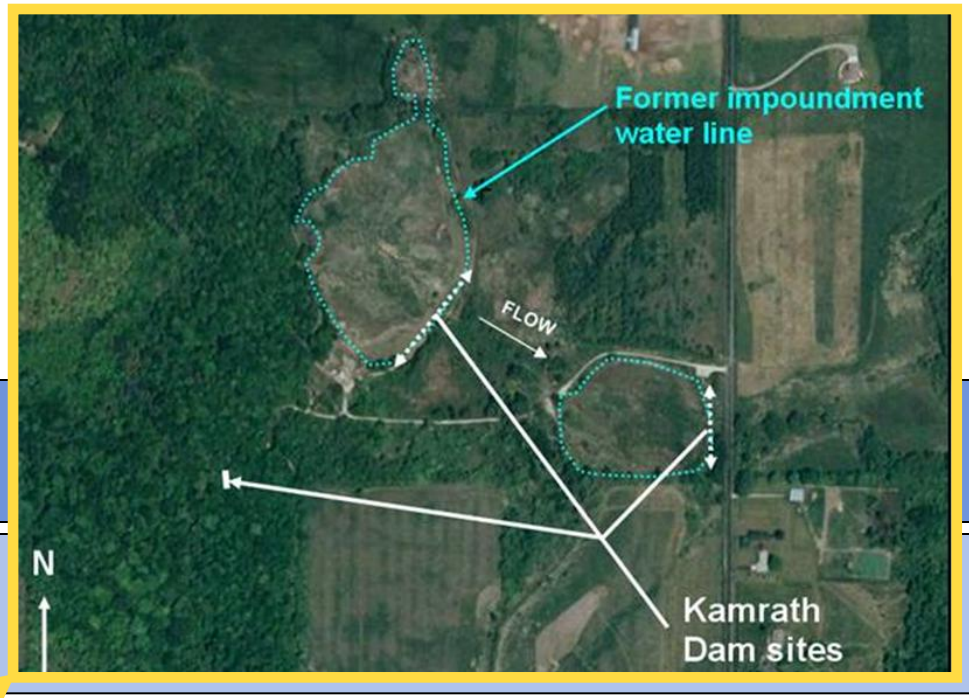

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DAM REMOVAL CLASSIFICATION SYSTEM

Little to No Sediment

SEDIMENT PRESENT?

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CONTAMINATED SEDIMENT FOUND IN IMPOUNDMENT, EXCEEDS BACKGROUD RIVERINE LEVELS

YES

Continue

RX (Contaminated Sediment)
Recovery Dependant on Sediment Management
(see contaminated sediment decision tree)

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Mad River

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So

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Fine Sediment (F)

U/S Channel Response

- Flow returns to pre-dam channel
- Returns to pre-dam channel
- Low sinuosity, Degrade to armor bed
- Single stem; Degrade to regime slope

U/S Sediment Response

- Exposed sediment will need time to revegetate
- Stable little to no erosion
- Gradual D / S transport both through headcut & surface erosion or diffusion
- Headcuts, then widens; Accelerated D / S transport & suspension

System Response

- Immediate 100% recovery
- Full recovery within 1 growing season
- Minor short term impact to no impact
- Can cover D/S bed reaches for short period of time
- Potential short term impacts due to turbidity

moved

wn-cut

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Johnson State College Dam

R2-N1
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Union City
Yoakum Brook
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Pursel Mill

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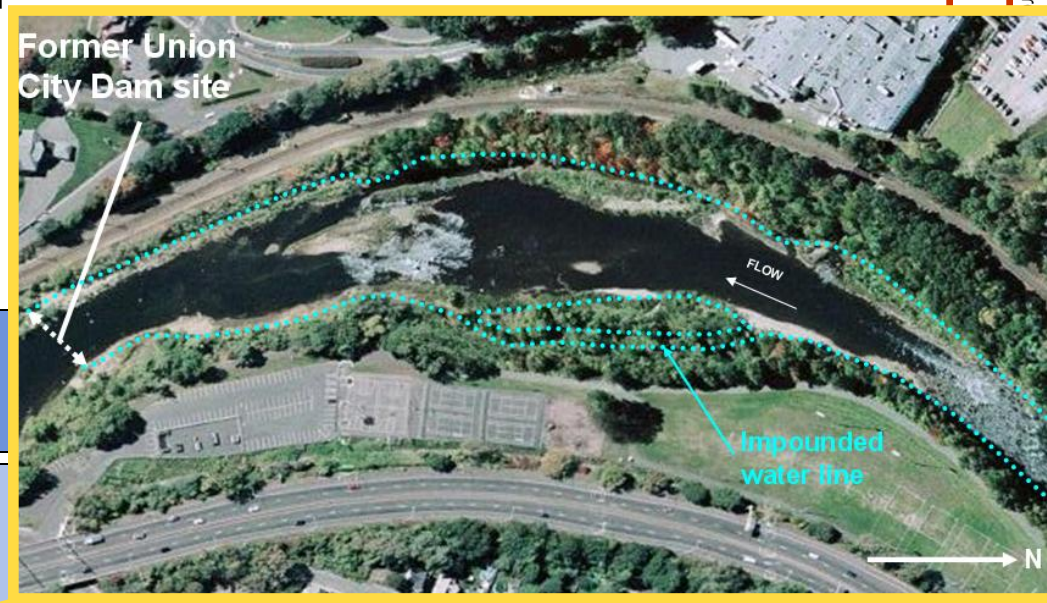

U/S Channel Response

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Single stem; Degrade to regime slope

U/S Sediment Response

Exposed sediment will need time to revegetate

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System Response

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Relative Recovery Time

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Highly Defined Legacy Channel? (L)

YES

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No Sediment (0)

Minimal Sediment (1)

Significant Sediment (2)

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Coarse Sediment (C)

Fine Sediment (F)

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System Response

Immediate 100% recovery	Full recovery within 1 growing season	Minor short term impact to no impact	Can cover D/S bed reaches for short period of time	Potential short term impacts due to turbidity	Recovery accelerated due to limited channel adjustment

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Narrow (N) | Wide (W) | Narrow (N) | NO | Highly Defined Legacy Channel? | NO | Wide (W) $W_{Imp} > 2W_{Ch}$

Significant Sediment (2)

Coarse Sediment (C) | Fine Sediment (F)

Variable Sinuosity, May Degrade Or Bifurcate

Higher sinuosity Degrades to armor or equil. slope

Headcut U/S then widening w/ some surface erosion & re-deposition. Overbank sediment remains

Incised channel, Lateral cuts, Floodplain formation

LEMENTED IF QUANTITY OF IMPOUNDED SEDIMENT EXCEEDS D/S CAPACITY

NO

System Response

Immediate 100% recovery

Full recovery within 1 growing season

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Can cover D/S bed reaches for short period of time

Potential short term impacts due to turbidity

Recover accelerated due to limited channel adjustment

Impact & timing dependant on quantity mobilized & D/S channel capacity

Potential short-term impacts due to turbidity, based on mobile quantity

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Raymond Brook
Ed Bills Pond

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Community Lake
Bilington St.
Merrimack Village

R7-W2F
Saw Mill
Scovill Reservoir
Glacial Lake Hitchcock
Red Cedar Lake

RL
Platts Mill
Union City
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Narrow (N)

NO

Highly Defined Legacy Channel?

NO

Wide (W)

NO

Significantly Wide (W+)
> Meander Belt W or $5W_{Ch}$

YES

Significant Sediment (2)

Fine Cohesive (F_C)

Fine Non-Cohesive (F_{NC})

Single stem, significant Degradation Or Bifurcation once channel widens

Higher sinuosity Degrades to armor or equil. slope

Incised channel, dramatic widening shifts

Incised channel, Lateral cuts, Floodplain formation

revegetate

diffusion

suspension

sediment remains

remains

SEDIMENT MANAGEMENT OPTION IMPLEMENTED IF QUANTITY OF IMPOUNDED SEDIMENT EXCEEDS D/S CAPACITY

NO

System Response

Immediate 100% recovery	Full recovery within 1 growing season	Minor short term impact to no impact	Can cover D/S bed reaches for short period of time	Potential short term impacts due to turbidity	Recovery accelerated due to limited channel adjustment	Impact & timing dependant on quantity mobilized & D/S channel capacity	Potential short-term impacts due to turbidity, based on mobile quantity	potential to smother D/S reaches w/ extended recover depending on carrying capacity	High sediment loads can greatly impact D/S system but much overbank sed. remains	High turbidity can greatly impact D/S system & remaining sediment consolidates

Classification & Example Sites

R0-N0
Freight Street
McGowan
McPherrin
Pizzini

R1-W0
Kamrath Dams
Johnson State
College Dam

R2-N1
Edwards
Bushy Hill
Chase Brass
Seber

R3-N2C
Union City
Yoakum Brook
West Heinkiker
Gruendyke
Pursel Mill

R4-N2F
Castle Fin

R5-W2L
Cuddebackville
Raymond Brook
Ed Bills Pond

R6-W2C
Anaconda
Community Lake
Bilington St.
Merrimack Village

R7-W2F
Saw Mill
Scovill Reservoir
Glacial Lake Hitchcock
Red Cedar Lake

R8-W+2C
Bunnels Pond
Jenkins

R9-W+2F_c
Norwalk Mill Pond
Ward Paper Mill
Mackenzie
Lake Whitney
Brewster Creek

R10-W+2F_{NC}
Zemko
Plimco
Plainsboro-
Canberry

RL
Platts Mill
Union City
Millport Conservancy
Lake Switzerland
Mad River

Relative Recovery Time

Simple Project. Quick 100% Recovery, No Remnant sediment

Small to moderate amount of sediment, most mobilizes within <5yrs

Complex Project
Slow Recovery
lg. amt. of sediment remains on overbank

Recovery Limited; May Never Fully Recover

DAM REMOVAL CLASSIFICATION SYSTEM

Little to No Sediment

SEDIMENT PRESENT?

YES

CONTAMINATED SEDIMENT FOUND IN IMPOUNDMENT, EXCEEDS BACKGROUD RIVERINE LEVELS

YES

Continue

RX (Contaminated Sediment)
Recovery Dependant on Sediment Management
(see contaminated sediment decision tree)

D/S CHANNEL DEGRADED or SOMETHING CAUSES CHANNEL TO INCISE BELOW THE ORIGINAL RIVERBED

YES

RL: Recovery Limited- Upstream channel headcuts below original riverbed.

DAM SILL LEFT IN PLACE, PARTIAL WIDTH REMOVAL OR NEW STRUCTURE ADDED

YES

RL: Recovery Limited- All or portion of U/S channel remains perched on Impounded sediments.

Uncontrolled headcut extends U/S of impoundment. Can lead to unraveling of U/S channel

Some possible impoundment-like characteristics remaining. System will down-cut when remained of sill/dam is eventually blown out or removed

Narrow (N) $W_{Imp} \approx W_{Ch}$

Wide (W) $W_{Imp} > 2W_{Ch}$

Significantly Wide (W+) $W_{Imp} >$ Meander Belt W or $5W_{Ch}$

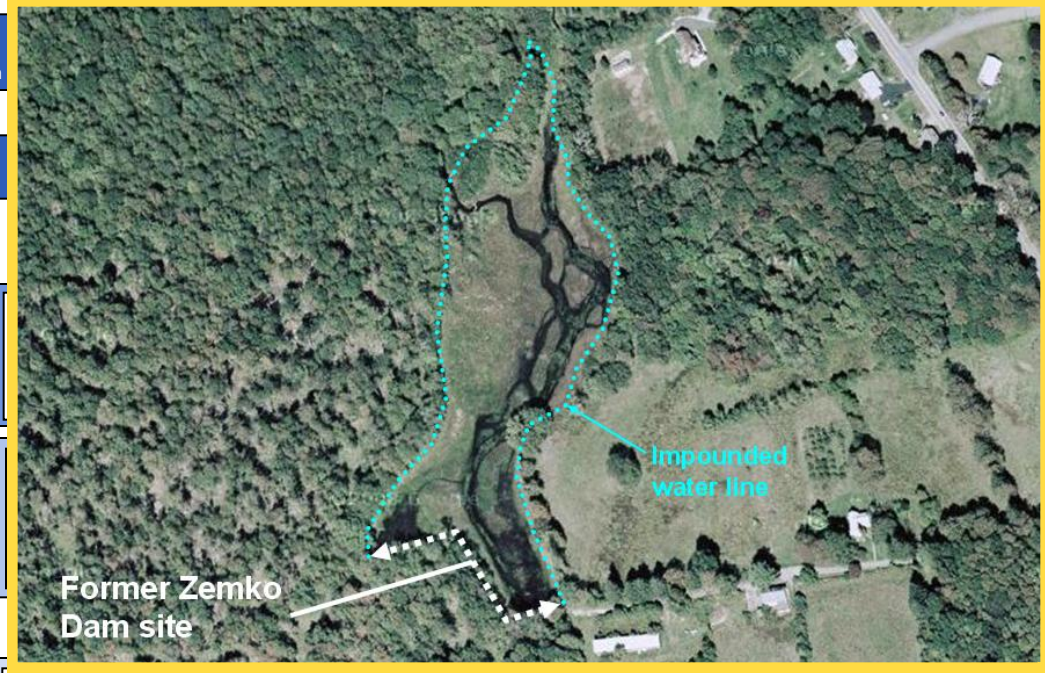
YES

No Sediment (0)

Significant Sediment (2)

Fine Cohesive (F_C)

Fine Non-Cohesive (F_{NC})



U/S Channel Response

Flow returns to pre-dam channel

Single stem, significant Degradation Or Bifurcation once channel widens

Higher sinuosity Degrades to armor or equil. slope

U/S Sediment Response

Exposed sediment will need time to revegetate

Incised channel, dramatic widening shifts

Incised channel, Lateral cuts, Floodplain formation

...ENT EXCEEDS D/S CAPACITY

NO

System Response

Immediate 100% recovery

Full recovery within 1 growing season

Minor short term impact to no impact

Can cover D/S bed reaches for short period of time

Potential short term impacts due to turbidity

Recovery accelerated due to limited channel adjustment

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Future Work – Refinement

Need quantifiable metrics to refine the threshold values

- impoundment width ratios
- sediment characterization/quantity
- system responses

Need field measurements on multiple sites (>10 years old)

Need to add a simple sediment carrying capacity protocol

Need to add ecological response

Integration into Decision Framework for Dam Removal and Sediment Management by the Subcommittee on Sedimentation

Subcommittee on Sedimentation Guideline Objective

- Provide a decision framework to determine the level of assessment needed to evaluate dam removal sediment impacts.
- Determine type & level of
  - data collection,
  - analyses,
  - modeling, and
  - monitoring necessary

RECLAMATION

Secretary of the Interior

Assistant Secretary for Water and Science

Advisory Committee on Water Information

Subcommittee on Sedimentation (SOS)

RECLAMATION

Dam Removal Sediment Analysis Steps

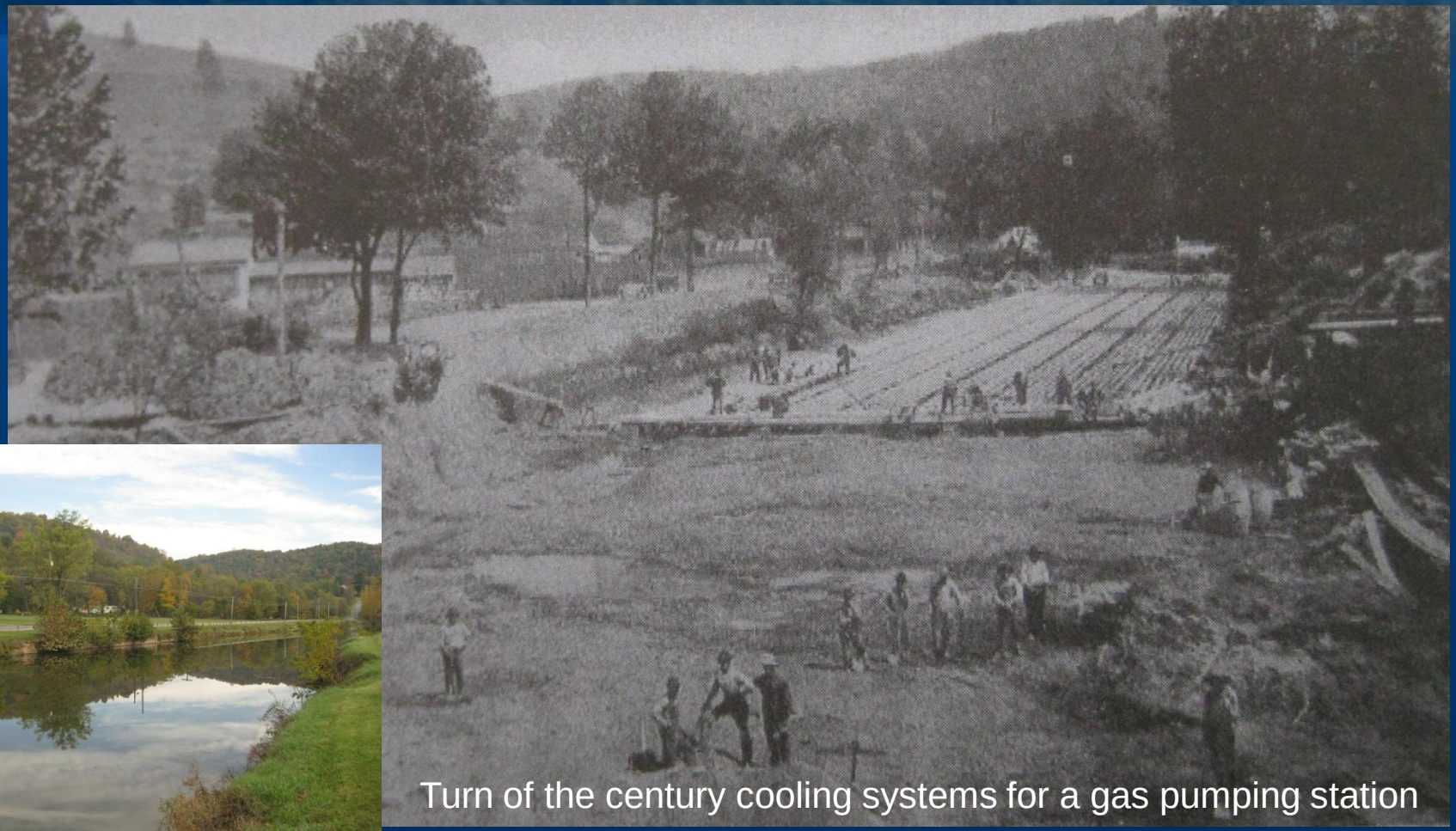
- Understand project goals and objectives
- Reconnaissance and data gathering
- Characterize reservoir sediment
- Assess contaminants
- Compare the reservoir sediment volume to the stream's average annual sediment load
- Develop dam removal and sediment management alternatives
- Predict reservoir and downstream effects
- Assess prediction confidence
- Determine if sediment impacts are tolerable
- Develop monitoring and adaptive management plan

RECLAMATION

Acknowledgements:

James MacBroom – Milone & MacBroom, Inc.
Brian Graber – American Rivers
Joe Rathbun – Michigan Department of Natural Resources
Tim Randle – Bureau of Reclamation

And there are always unpredictable surprises!



Turn of the century cooling systems for a gas pumping station